11-18
5-47

TECHNICAL NOTE

D-450

NOISE CONSIDERATIONS FOR MANNED REENTRY VEHICLES

By David A. Hilton, William H. Mayes, and Harvey H. Hubbard

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON September 1960

1H

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL NOTE D-450

NOISE CONSIDERATIONS FOR MANNED REENTRY VEHICLES

By David A. Hilton, William H. Mayes, and Harvey H. Hubbard

SUMMARY

L
1
0
4
4

Noise measurements pertaining mainly to the static firing, launch, and exit flight phases are presented for three rocket-powered vehicles in the Project Mercury test program. Both internal and external data from onboard recordings are presented for a range of Mach numbers and dynamic pressures and for different external vehicle shapes.

The main sources of noise are noted to be the rocket engines during static firing and launch and the aerodynamic boundary layer during the high-dynamic-pressure portions of the flight. Rocket-engine noise measurements along the surface of the Mercury Big Joe vehicle were noted to correlate well with data from small models and available data for other large rockets. Measurements have indicated that the aerodynamic noise pressures increase approximately as the dynamic pressure increases and may vary according to the external shape of the vehicle, the highest noise levels being associated with conditions of flow separation. There is also a trend for the aerodynamic noise spectra to peak at higher frequencies as the flight Mach number increases.

INTRODUCTION

Manned space flight operations involve some potentially serious noise environments both inside and outside the space vehicle. (See refs. 1 to 4.) These problems arise for some rather obvious reasons; namely, the use of very powerful engines, the high airspeeds attained within the earth's atmosphere, and the need to save weight in the basic structure in order to accommodate the maximum payload. There is a need for maintaining the integrity of the space vehicle structure and for eliminating malfunction of its sensitive control equipment. There is also a need to control the inside noise environments of the occupied area to insure safety of the occupants, and to allow them to communicate with the ground station and to perform other assigned duties.

Although some analytical studies have been made of the noise environments of ground-launched space vehicles (refs. 1 and 2), very little measured data are generally available, particularly for large vehicles. Recent flight tests of three rocket-powered vehicles in connection with Project Mercury have, however, provided some data of this type for a range of operating conditions. Some of these data are presented and are compared, where possible, with results from other studies. An attempt is also made to generalize these data for use in predicting the noise environments of future space vehicles.

SOURCES OF NOISE

L
1
0
4
4

The noise sources that are of concern for manned reentry vehicles are indicated schematically in figure 1. A flight path extends from launch through the exit phase to space flight conditions and reentry. Also indicated on figure 1 are the major sources of noise in each phase of the flight. At lift-off and also during static firing, the main sources of noise are the rocket engines. During the exit phase of the flight, particularly during conditions of high dynamic pressure, the main noise comes from the fluctuating pressures in the aerodynamic boundary layer. Internal equipment such as air conditioners, etc., are expected to be the main source of noise during space flight, whereas during the reentry phase the noise is expected to be of aerodynamic origin. This paper contains information relating mainly to the launch and exit phases of the flight during which time the highest noise levels are encountered.

TEST VEHICLES

Recent noise research studies accomplished in connection with Project Mercury have provided some information for the various noise sources noted in figure 1, by use of the test vehicles schematically shown in figure 2. The test vehicles shown are the Big Joe, which was instrumented by NASA Space Task Group personnel and fired from Cape Canaveral, Florida, and the Little Joe 2 and Little Joe 1B vehicles, which were instrumented by Langley Research Center personnel and fired from Wallops Island, Virginia. The approximate location of both external and internal microphone stations are indicated. The internal microphones were located at the position where the pilot's head would be located, approximately 6 inches from the capsule side wall. The flight data were recorded with the aid of onboard tape recorders which were recovered after the flights. It should be noted that the external geometries of the vehicles differ, and that the Mach number and free-stream dynamic-pressure ranges for these vehicles are also different.

NOISE AT LIFT-OFF

Data relating to the external noise environment of an entire launch vehicle, including the manned compartment and the booster sections, are given in figure 3. Sound pressure levels in decibels (reference level, 0.0002 dyne/cm^2) are plotted for various distances h/d, where h is the distance measured from the nozzle exit plane toward the nose of the vehicle, and d is the equivalent nozzle diameter. For a multiple-nozzle arrangement, d is assumed to be the diameter of a circular nozzle equivalent in area to the sum of the smaller ones. As a matter of interest, the thrust of large booster engines per unit nozzle exit area is nearly a constant. Thus, this quantity d is essentially proportional to the square root of the total thrust of the vehicle.

L-1044

The locations of the two lines (fig. 3) were based on experimental results from model supersonic jets and small rocket engines. The line on the left represents estimated sound pressure levels along the outside of the vehicle for the case where the rocket-engine exhaust exits straight down and is not deflected. (See refs. 5 and 6.) Such a condition as this might exist when the vehicle is at a high enough altitude to be outside of the ground effects but still at some low flight velocity. It has been found in some unpublished model studies that a turning of the exhaust stream results also in a turning of the noise field and by about the same amount. On this basis the line on the right has been drawn in to indicate the maximum sound pressure levels that would result from a 90° deflection of the exhaust stream.

Plotted on figure 3 also are several data points obtained for rocket engines of various thrust ratings. It will be noted that the data for large rocket engines fall generally between the extreme values of the lines. The only exceptions are the two data points on the extreme right. These apply to an engine having noise spectra which contain large discrete peaks resulting probably from rough burning. It can be seen that the sound pressure levels increase in general for stations closer to the nozzle exit, that is, for smaller values of h/d. Although this is a rather unsophisticated approach to predicting the sound pressure levels along the surface of the vehicle, the fact that data correlate well for a wide range of jet sizes gives confidence that it will be useful for larger thrust vehicles.

Of particular interest are the data indicated by the blocked-in symbols from unpublished work of William H. Mayes and Phillip M. Edge, which apply directly to the Atlas vehicle of Project Mercury. In addition to the overall sound pressure levels, it is of interest to know the spectra at various stations along the vehicle. As an example of the data obtained for the Atlas vehicle in the region where the manned capsule will be located, spectra for both external and internal measuring stations are included in figure 4. Sound pressure levels are shown for various octave bands in cps. The spectra measured at other external stations along the vehicle were of higher levels but did not differ appreciably in shape from the external spectra shown in figure 4. A procedure for correlating rocket engine sound spectrum levels in the region of the vehicle is given in reference 7.

The differences in sound pressure level between the external and internal spectra of figure 4 are an indication of the noise transmission loss associated with the capsule structure. Shown for comparison is the internal spectrum as estimated theoretically from pure inertia considerations of the mass law. (See ref. 8.) It may be seen that more noise reduction occurred at the lower frequencies than would be predicted. Other noise transmission studies conducted on this same capsule structure have also confirmed this finding. It is believed that this additional noise reduction at the low frequencies results from stiffness effects due to the characteristic shape of the capsule.

IN-FLIGHT NOISE

As an example of the type of data that have been measured in space vehicles, a time history of the internal capsule noise for the lift-off and subsequent free-flight operation of the Big Joe Mercury vehicle is shown in figure 5. These data from the work of William T. Lauten and David A. Hilton were obtained with the aid of an onboard tape recorder recovered after the flight. Some of the significant events such as launch, maximum dynamic pressure, and approximate reentry, etc., are indicated. The electrical-circuit noise, or so-called "hash level," was about 100 db as noted in figure 5 for the gain settings used in this experiment. It can be noted that the highest sound pressure levels were recorded during the time that the vehicle was operating at its maximum dynamic pressure, and it is believed that this noise is due to the aerodynamic boundary layer. As a result of exploratory communication studies with various types of personal flight equipment, there is some concern for the reliability of two-way voice communications in the presence of aerodynamic sound pressure levels which exceed 120 db.

In addition to the data illustrated in figure 5, similar onboard recordings have been successfully made for two Little Joe Mercury vehicles of the type illustrated in figure 2. The capsules were similar in shape but differed somewhat in their external forebody configurations. Little Joe tests have produced similar results; namely, the internal aerodynamic sound pressure levels were higher than those from the other major sources and persisted for a longer period of time. Thus, because of the relative importance of the aerodynamic noise, it is necessary to understand the manner in which this noise is related to vehicle geometry and performance in the Mach number and dynamic-pressure ranges of interest.

Consequently, the noise data from two of these tests have been plotted in figure 6 as a function of dynamic pressure q along with a curve of estimated maximum external sound pressure levels based on available wind-tunnel tests (ref. 9), flight tests of Norman J. McLeod and Gareth H. Jordan, and flight and rotating cylinder tests of reference 7. The estimated external sound pressure levels of the figure were calculated as follows:

$$\text{Sound pressure level} = 20 \log_{10}\left(\frac{0.006q}{p_{ref}}\right)$$

L-1044

where the reference pressure p_{ref} is equal to 4.177×10^{-7} lb/sq ft. The differences between the estimated external and the measured internal sound pressure levels are indications of the noise transmission loss through the structure.

It is noted that the internal noise pressures increase as the dynamic pressure increases, the noise pressures being roughly proportional to the dynamic pressure. The curve of small dashes applies to the Big Joe vehicle and is plotted in such a way that flight Mach numbers 1.0, 2.0, 3.0, and 4.0 are indicated. It will be noted that at any given value of dynamic pressure the lower sound pressure level is associated with the higher Mach number. Data for the Little Joe 2 vehicle, as shown by the solid curve, show similar results for the Mach number range up to nearly 6.0. It is believed that this reduction in internal sound pressure level at the higher Mach numbers may result from differences in the noise spectra.

In order to illustrate these differences, internal noise spectra in the Big Joe vehicle for the same value of dynamic pressure but for two different Mach numbers are shown in figure 7. In this figure, sound pressure level is plotted for various octave bands for both subsonic and supersonic Mach numbers. It is evident from the figure that the spectrum at the higher Mach number peaks at a higher frequency. This shift of the peak of the spectrum toward higher frequencies is believed to result in a greater transmission loss through the structure (ref. 8) and thus to lower inside sound pressure levels. It should be noted that these are internal spectra; the external spectra would be expected also to shift in this same manner and probably by a greater amount.

Another factor which was noted to be of significance with respect to the inside sound pressure levels is the outside geometry of the vehicle. Some of the effects of external geometry on the aerodynamic sound pressure levels are shown in figure 8. A dimensionless ratio of noise pressure to dynamic pressure is plotted as a function of Mach number for the three test configurations. The lowest noise pressures measured are for the Big Joe Mercury vehicle. In general, it can be seen that, for a given value of local dynamic pressure, the inside noise pressures decrease as the Mach number increases. For the reentry configuration where the blunt base is forward, the aerodynamic noise pressures were noted to be markedly lower than those during the exit phase. The reason for these lower noise pressures in reentry is not fully understood at the present time; however, they are believed to be due in part to the difference in capsule orientation (ref. 10) and also to Mach number effects.

L
1
0
4
4

Although some minor differences existed in construction and internal sound treatment, it is believed that the differences in the measured noise pressures between Little Joe 2 and the Big Joe vehicle may be ascribed mainly to differences in external geometry. Of particular interest is a direct comparison of the data for Little Joe 2 with that for Little Joe 1B. In this comparison the only significant difference in the two configurations was the presence of a Marman band spoiler on Little Joe 1B to increase its aerodynamic stability. The resulting internal noise pressures are seen to be markedly higher in this latter case. These noise pressure increases are due possibly to separated flow conditions induced by the spoiler and are of the same order of magnitude as those previously measured in a wind-tunnel model having separated flow and different external contours. (See ref. 11.)

Also of interest with regard to the excitation of the thin, external, heat-shield panels are the fluctuating surface pressures due to the spoiler. These external data are shown in figure 9 where the ratio of sound pressure to dynamic pressure is again shown as a function of Mach number. The horizontal line of small dashes represents the maximum values that would be estimated on the basis of available wind-tunnel and low-speed flight data. (See refs. 7 and 9.) The data measured with a surface pressure pickup on the conical section of the Little Joe 1B vehicle in the sketch are higher at some Mach numbers than the maximum values that would have been predicted for the "no spoiler" case. A distinguishing characteristic of the external noise is the existence of large-amplitude low-frequency disturbances, particularly at the lower Mach numbers. It should be emphasized that these data were measured at a single point on the vehicle and hence may apply directly to only a small area on its surface. Furthermore, the surface-pressure conditions at any point may be a function of Mach number and hence would probably vary as a function of time.

CONCLUDING REMARKS

The main sources of noise for a rocket-powered reentry vehicle are noted to be the engines during static firing and launch and the aerodynamic boundary layer during the high dynamic pressure portions of the flight. Rocket engine noise measurements along the surface of the Mercury Big Joe vehicle were noted to correlate well with data from small models and with available data for other large rockets. Measurements for three different flight vehicles have indicated that the aerodynamic noise pressures increase approximately as the dynamic pressure increases and may vary according to the external shape of the vehicle, the highest sound pressure levels being associated with conditions of flow separation. There is also a trend for the aerodynamic noise spectra to peak at higher frequencies as the Mach number increases.

L
1
0
4
4

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., April 12, 1960.

REFERENCES

1. Von Gierke, H. E.: Vibration and Noise Problems Expected in Manned Space Craft. Noise Control, vol. 5, no. 3, May 1959, pp. 9-16.

2. Nadel, Aaron B.: Auditory Noise and Vibration Problems for Manned Space Vehicles. Res. Memo. RM 59TMP-50, General Electric Co., Oct. 20, 1959.

3. Dyer, I., Franken, P. A., and Ungar, E. E.: Noise Environments of Flight Vehicles. Noise Control, vol. 6, no. 1, Jan.-Feb. 1960, pp. 31-40, 51.

4. Franken, Peter A., Kerwin, Edward M., Jr., and the Staff of Bolt Beranek and Newman, Inc. (Cambridge, Mass.): Methods of Flight Vehicle Noise Prediction. WADC Tech. Rep. 58-343, ASTIA Doc. No. AD 205776, U.S. Air Force, Nov. 1958.

5. Mayes, William H., Lanford, Wade E., and Hubbard, Harvey H.: Near-Field and Far-Field Noise Surveys of Solid-Fuel Rocket Engines for a Range of Nozzle Exit Pressures. NASA TN D-21, 1959.

6. Von Gierke, H. E.: Recent Advances and Problems in Aviation Acoustics. Presented at Third International Congress on Acoustics (Stuttgart, Germany), Sept. 1-8, 1959.

7. Eldred, Ken: Prediction of Sonic Exposure Histories. Proceedings of the Symposium on Fatigue of Aircraft Structures, WADC Tech. Rep. 59-507, U.S. Air Force, Aug. 1959, pp. 396-415.

8. Nichols, R. H., Jr., Sleeper, H. P., Jr., Wallace, R. L., Jr., and Ericson, H. L.: Acoustic Materials and Acoustical Treatments for Aircraft. Jour. Acous. Soc. Am., vol. 19, no. 3, May 1947, pp. 428-443.

9. Willmarth, William W.: Wall Pressure Fluctuations in a Turbulent Boundary Layer. NACA TN 4139, 1958.

10. Callaghan, Edmund E.: An Estimate of the Fluctuating Surface Pressures Encountered in the Reentry of a Ballistic Missile. NACA TN 4315, 1958.

11. Regier, Arthur A.: Noise, Vibration, and Aircraft Structures. Preprint no. 631, S.M.F. Fund Preprint, Inst. Aero. Sci., Jan. 23-26, 1956.

L-1044

L-1044

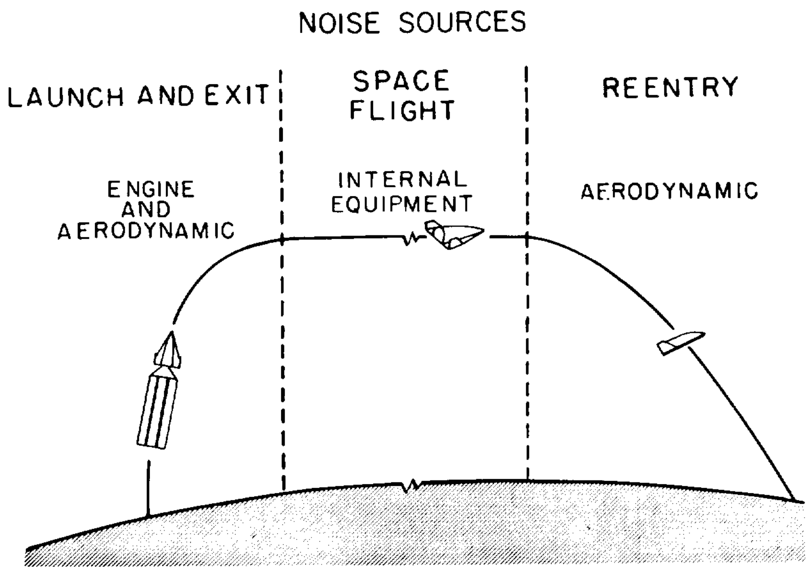

Figure 1

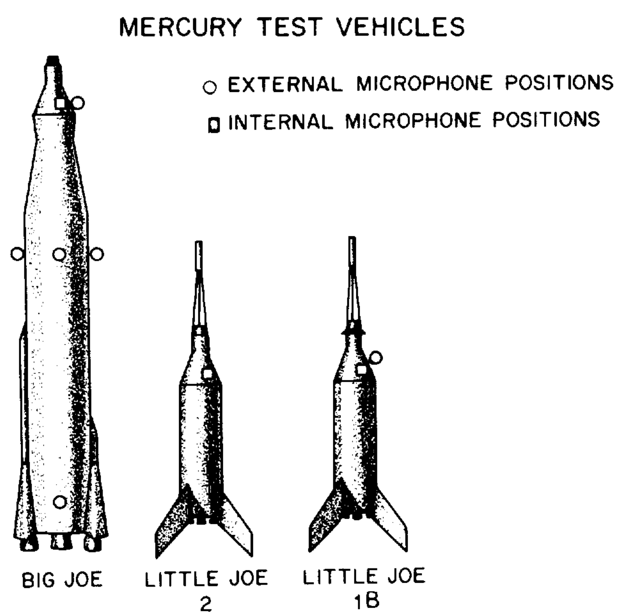

Figure 2

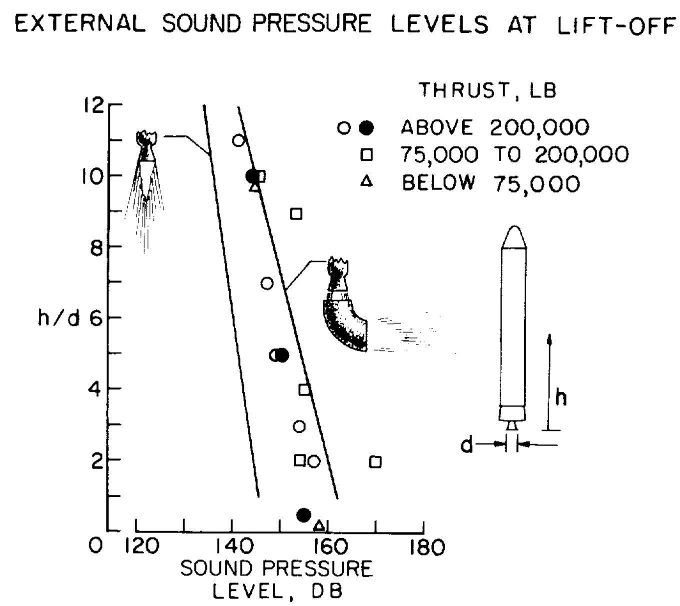

Figure 3

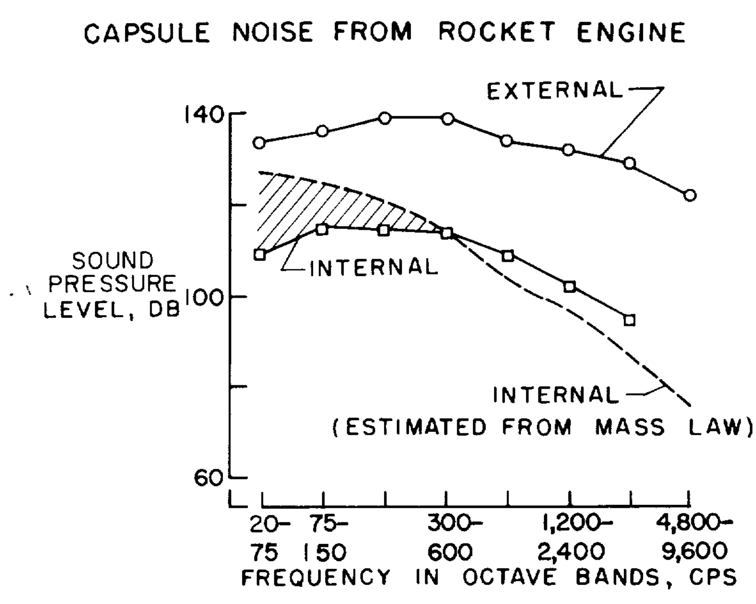

Figure 4

L-1044

L-1044

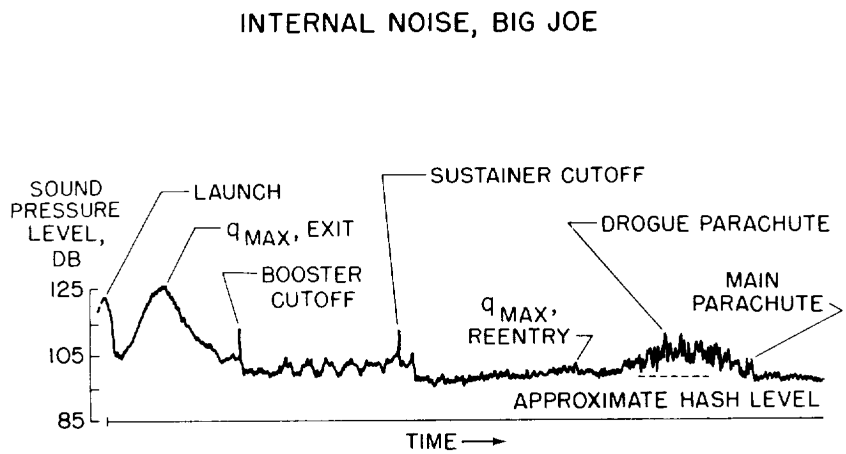

Figure 5

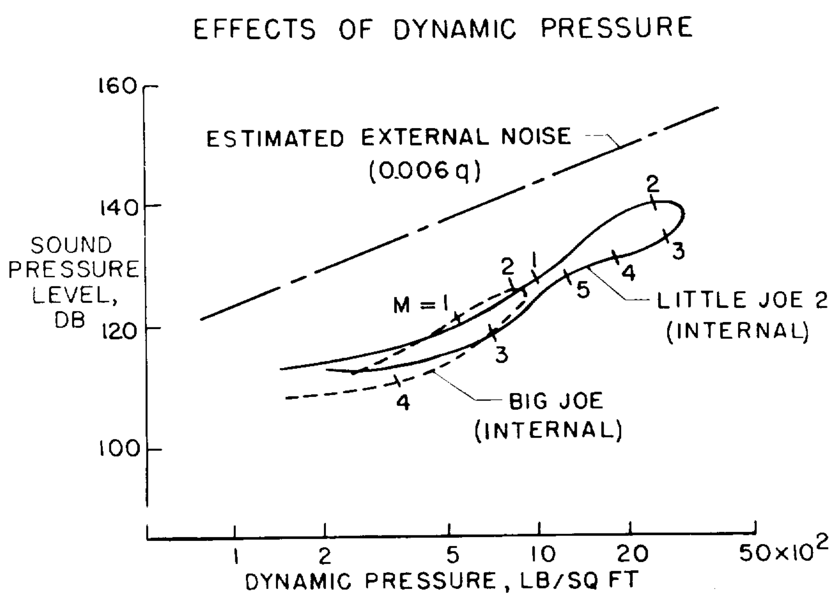

Figure 6

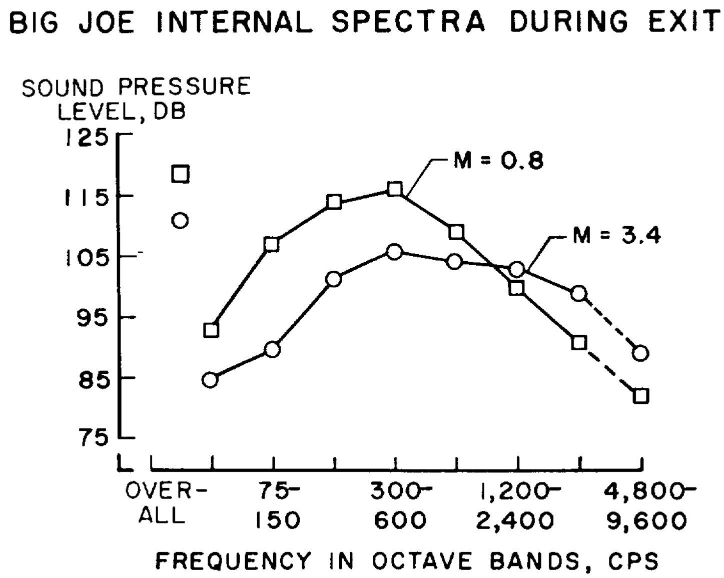

Figure 7

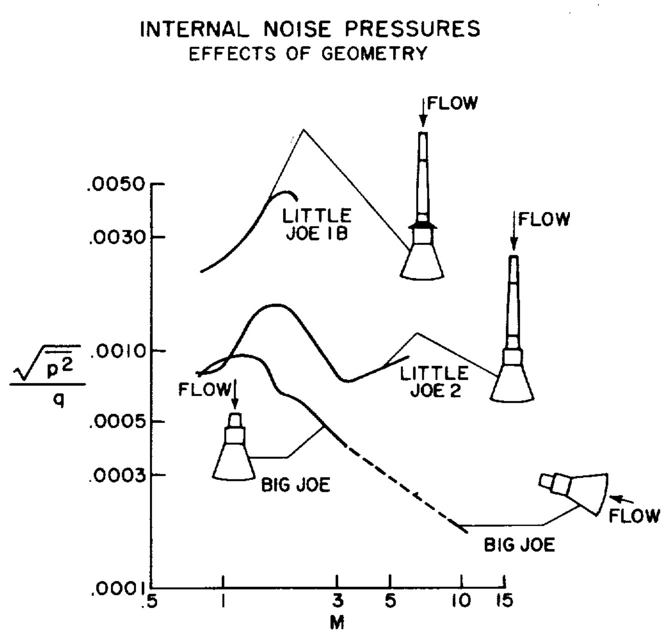

Figure 8

L-1044

L-1044

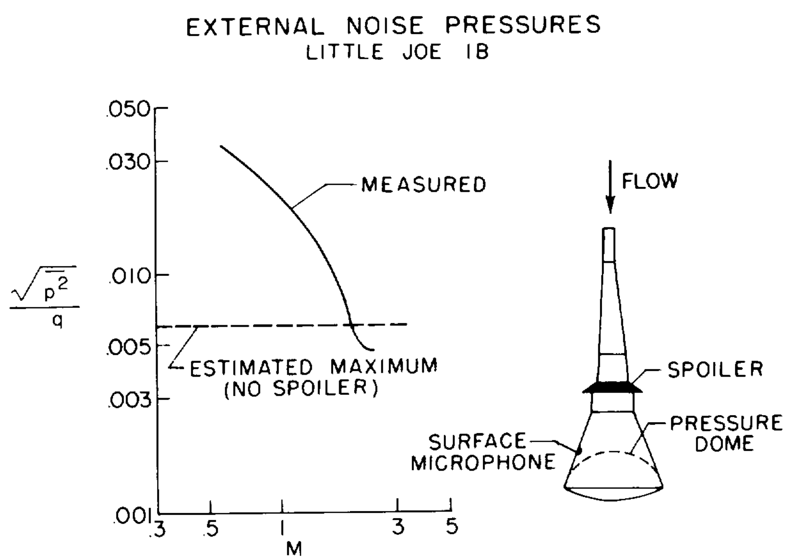

Figure 9

NASA TN D-450
National Aeronautics and Space Administration.
NOISE CONSIDERATIONS FOR MANNED REENTRY VEHICLES. David A. Hilton, William H. Mayes, and Harvey H. Hubbard. September 1960. 13p. OTS price, $0.50. (NASA TECHNICAL NOTE D-450)

Noise measurements pertaining mainly to the static firing, launch, and exit flight phases are presented for three rocket-powered vehicles in the Project Mercury test program. Both internal and external data from onboard recordings are presented for a range of Mach numbers and dynamic pressures and for different external vehicle shapes.

(Initial NASA distribution: 2, Aerodynamics, missiles and space vehicles; 4, Aircraft safety and noise; 5, Atmospheric entry; 20, Fluid mechanics.)

Copies obtainable from NASA, Washington

I. Hilton, David A.
II. Mayes, William H.
III. Hubbard, Harvey H.
IV. NASA TN D-450

NASA

NASA TN D-450
National Aeronautics and Space Administration.
NOISE CONSIDERATIONS FOR MANNED REENTRY VEHICLES. David A. Hilton, William H. Mayes, and Harvey H. Hubbard. September 1960. 13p. OTS price, $0.50. (NASA TECHNICAL NOTE D-450)

Noise measurements pertaining mainly to the static firing, launch, and exit flight phases are presented for three rocket-powered vehicles in the Project Mercury test program. Both internal and external data from onboard recordings are presented for a range of Mach numbers and dynamic pressures and for different external vehicle shapes.

(Initial NASA distribution: 2, Aerodynamics, missiles and space vehicles; 4, Aircraft safety and noise; 5, Atmospheric entry; 20, Fluid mechanics.)

Copies obtainable from NASA, Washington

I. Hilton, David A.
II. Mayes, William H.
III. Hubbard, Harvey H.
IV. NASA TN D-450

NASA

NASA TN D-450
National Aeronautics and Space Administration.
NOISE CONSIDERATIONS FOR MANNED REENTRY VEHICLES. David A. Hilton, William H. Mayes, and Harvey H. Hubbard. September 1960. 13p. OTS price, $0.50. (NASA TECHNICAL NOTE D-450)

Noise measurements pertaining mainly to the static firing, launch, and exit flight phases are presented for three rocket-powered vehicles in the Project Mercury test program. Both internal and external data from onboard recordings are presented for a range of Mach numbers and dynamic pressures and for different external vehicle shapes.

(Initial NASA distribution: 2, Aerodynamics, missiles and space vehicles; 4, Aircraft safety and noise; 5, Atmospheric entry; 20, Fluid mechanics.)

Copies obtainable from NASA, Washington

I. Hilton, David A.
II. Mayes, William H.
III. Hubbard, Harvey H.
IV. NASA TN D-450

NASA

NASA TN D-450
National Aeronautics and Space Administration.
NOISE CONSIDERATIONS FOR MANNED REENTRY VEHICLES. David A. Hilton, William H. Mayes, and Harvey H. Hubbard. September 1960. 13p. OTS price, $0.50. (NASA TECHNICAL NOTE D-450)

Noise measurements pertaining mainly to the static firing, launch, and exit flight phases are presented for three rocket-powered vehicles in the Project Mercury test program. Both internal and external data from onboard recordings are presented for a range of Mach numbers and dynamic pressures and for different external vehicle shapes.

(Initial NASA distribution: 2, Aerodynamics, missiles and space vehicles; 4, Aircraft safety and noise; 5, Atmospheric entry; 20, Fluid mechanics.)

Copies obtainable from NASA, Washington

I. Hilton, David A.
II. Mayes, William H.
III. Hubbard, Harvey H.
IV. NASA TN D-450

NASA